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DISCUSSION OF JET TRANSPORT ECONOMICS INFLUENCE ON AIRPORT AND AIRWAY PROCEEDINGS—SEPARATE 241

LOUIS A. NEES, A. M. ASCE, and CHARLES F. PHILLIPS.[1]—The author's paper gives the impression that the piston engine-driven aircraft is on its way out. The high specific fuel consumption of the jet engine, its low power output at lower speeds all contribute to reserve a place for the piston-engined aircraft in the field of shorter hauls. We venture to say that it will never replace this type for hauls of less than 400 miles.

In the military field aircraft gross weights have already gone over 250,000 lbs. It is quite likely that commercial aircraft will follow this trend. For international airport design criteria we would recommend extending the capacity to 400,000-lb. aircraft rather than 300,000 lb. as the author suggests. First, the trend seems to be to an aircraft approaching that weight as a practicable limit. Second, the use of dual tandem and truck-type landing gears have markedly improved the capacity of pavements. Table No. 1[2] shows the relative thickness of concrete pavement required for aircraft of 200,000—300,000 and 400,000 lbs. gross weight using dual tandem wheel assemblies.

TABLE I

Gross Weight of Aircraft	f_c (in.) (1)	Cost/Sq Yd	Estimated Cost 1-10,000' x 300' runway	% Increase
200,000	10	$5.80	$1,930,000	--
300,000	15	8.00	2,660,000	37
400,000	16	8.40	2,790,000	5

Note: Based on k = 100, f_c flexure = 700# sq. in. It is fairly evident that as the weight increases above 200,000 lbs. the cost of a unit of capacity increase decreases markedly.

The thin wing naturally poses problems of accommodating landing gear. It is our impression that the present tire pressures and sizes adopted in the military field to a great extent have been governed considerably by their effect on pavement stresses. The small diameter high-pressure tire required in our relatively heavy jet fighters causes high local shearing stresses in the top few inches of the pavement. In the heavier aircraft such as the bombers the problem has been successfully met by the introduction of the truck-type landing gear which consists of four oleos, one pair arranged similarly to truck wheels, the

1. Chf., Eng. Branch, and Chf., Mechanical Section, respectively, Installations Div., Headquarters, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.
2. Part XII, Chapter 3, OCE Manual.

distance between the front and rear sets being on the order of 30 to 40 feet. By use of multiple wheel assemblies in each oleo, lower pressure tires and lower pavement stresses are attained. There appears no reason why this system should not be practical and economical for commercial aircraft.

The "foreign body" problem has plagued the Air Force ever since the advent of the jet aircraft. Special emphasis is placed not only upon the "housekeeping" but also upon the maintenance of grounds as well. The problem is serious, common to commercial and military operations and, in our opinion, will be overcome principally by increasing emphasis on housekeeping and maintenance.

The author's suggestion that jet aircraft be towed out to the end of the runway before starting the engines has considerable merit from the noise viewpoint. However, this problem must be carefully examined for each individual case because of the decreasing effectiveness of attenuation with distance. The over-all sound pressure level of a modern jet engine aircraft at the engines is about 145 db (referred to 0.0002 dynes/sq. cm.). Assuming the end of the runway to be about 1000 feet from the terminal or nearest shops the approximate sound pressure level at the latter places would be approximately 103 db. This is still above the safety criterion of 95 db as established by Bolt, Beranek and Newman.[3] At about 2000 feet the over-all level would just about lie at the damage risk level. Jet engines produce a high amplitude noise over a relatively wide frequency range. Figure No. 1 shows the sound pressure spectrum for a typical modern engine together with the damage risk spectrum which is the pressure level above which temporary or even permanent damage can be caused by continued exposure. The low frequencies, 20—300 cps, are the most difficult and expensive to attenuate.

The author's suggestions for prevention of noise in areas contiguous to the airport are practical but increasing consideration must be given in the light of the data in Figure No. 1 to protection of people engaged in maintenance and overhaul operations. Here also barriers and absorption devices may have their place. Another scheme which is under study in the aircraft industry and the Air Force is the provision of portable muffling devices which surround the engine in the aircraft during maintenance run-ups.

While the statement in the paper that the solution to the noise problem is complex and not easy to work out is concurred in, the writers are more optimistic than the author in this respect. The Air Force has given this problem a great deal of study in the past several years. Already great strides have been made by it and the other services in producing adequate sound attenuation in engine test cells where the problems are severe. Much has been learned and it is felt that practical solutions for the problems of airport noise control are at hand or at least within reach.

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3. "Noise Control Analysis and Recommendations for the Kelly, Robins, McClellan and Norton Air Force Bases," by Bolt, Beranek and Newman, Consultants in Acoustics, February 14, 1951.

The author should be complimented for his look into the future. It is not too early and in many respects may already be a little late for the airport planners and governing bodies to tackle these problems intensively and aggressively.

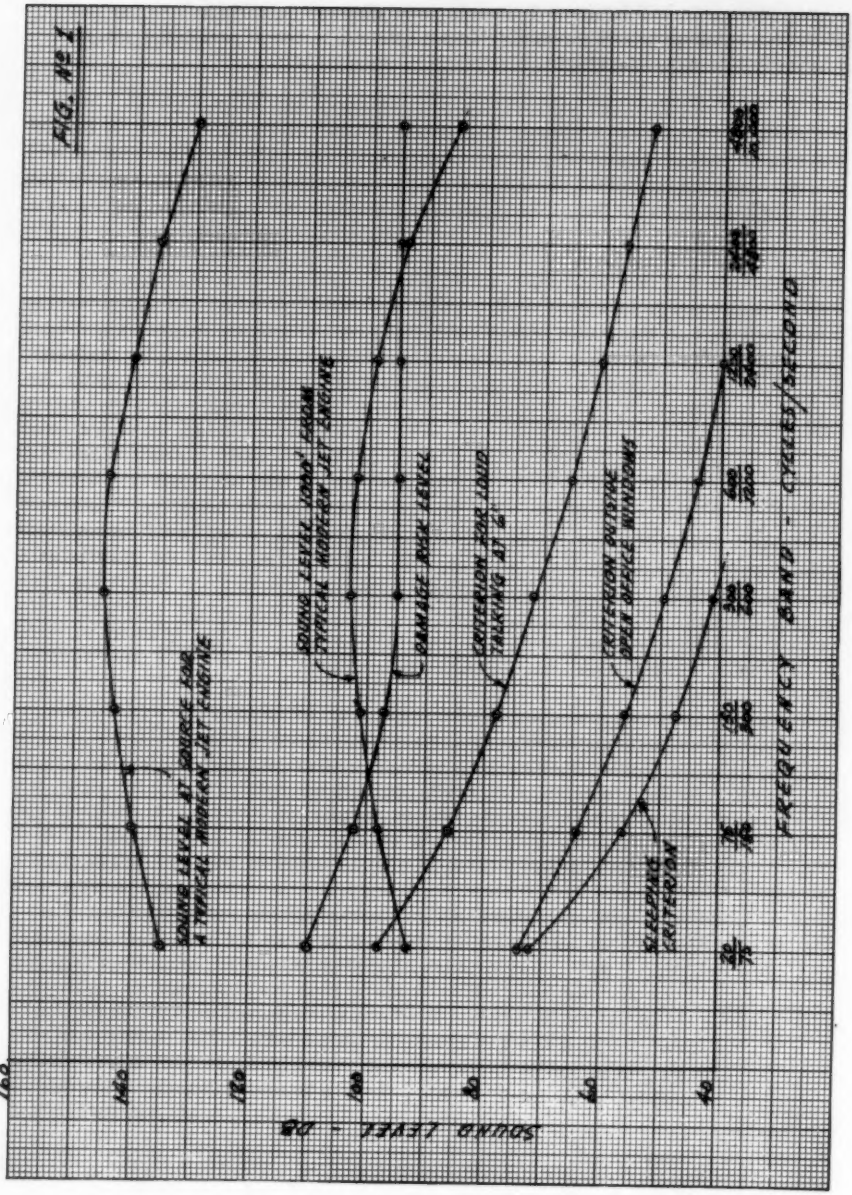
FIG. No 1
SOUND LEVEL - DB
160
140
120
100
80
60
40
FREQUENCY BAND - CYCLES/SECOND
SOUND LEVEL AT SOURCE FOR A TYPICAL MODERN JET ENGINE
SOUND LEVEL (DB) FROM TYPICAL MODERN JET ENGINE
NOISE REDUCTION
CRITERION FOR LOUD TALKING AT 3'
CRITERION OUTSIDE BRICK VENEER WINDOWS
SLEEPING CRITERION

DISCUSSION OF BASE COURSE AND BITUMINOUS PAVEMENT REQUIREMENTS PROCEEDINGS—SEPARATE 424

E. W. BAUMAN, M. ASCE[1].—The authors in their article on "Base Course and Bituminous Pavement Requirements" have provided valuable information to a phase of our engineering science which, until recent years, depended largely upon developments of the Highway Engineers for proper design criteria to be used in the construction of airport bases and runways.

Their discussion of base compaction, as affected by varying tire pressure, and the effect of fuel spillage on asphaltic concrete runways is particularly enlightening. Results of tests currently underway, studying methods for eliminating or reducing the detrimental effect of fuel on pavements, as referred to in the article, are awaited with considerable interest by engineers designing airports for use by jet planes.

The authors give proper recognition to the importance of good quality aggregates for the construction of satisfactory bases. However, their classification of crushed slag in a grouping of secondary importance, along with gravel, limerock and coral, rather than in the classification of "excellent" along with crushed limestone, granite and traprock, is rather circumspect, and in order to avoid any misconception which readers of the article might form from the authors inference, the following discussion seems appropriate.

Slag, because of its rough and vesicular surface texture and the cubical shape into which it normally crushes, is one of the best aggregates to be used for the construction of bases and roadway or runway surfaces, where high stability and load-carrying capacity are important. The slag screenings used in binding coarse aggregate to form macadam base, possess hydraulic or "setting-up" properties so that in due time the slab forms a condition approaching that of Portland cement concrete.

Results of laboratory and field investigations, undertaken to evaluate various aggregates for use in base construction, as conducted during the years, clearly demonstrates the high rating of slag as an aggregate. Results of plate bearing tests conducted by engineers of the Ohio State Highway Department on macadams and bases constructed with various types of aggregate have shown that higher values are available from slag macadam than with either crushed limestone or gravel.[2]

A rather unusual investigation recently conducted under auspices of the U. S. Civil Aeronautics Administration at their Indianapolis, Indiana

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1. Managing Director, National Slag Assn., Washington, D. C.
2. Research Bulletin No. 3, "Experimental Single Course 8" Macadam Base", March 15, 1950, State of Ohio Dept. of Highways, Columbus, Ohio; also Supplement No. 1 thereto dated September 12, 1950.

Laboratory, attempting to determine the structural properties of granular base materials, particularly their ability to transmit applied loads through the base and into the subgrade, again demonstrated the high bearing value of slag as contrasted to other type aggregates. In the Conclusions of a report covering the first series, it is recorded that: "In load transmission tests of base courses, the crushed slag should be the best of the four materials tested. . . ."[3]

These same characteristics of slag which make it an excellent base course material are also the factors which provide high stability of bituminous mixes when it is used as the coarse aggregate. Results obtained from an extensive investigation by the Corps of Engineers, U. S. Army, at their Vicksburg Experimental Station to demonstrate the stability available from bituminous mixtures compacted under various conditions and involving different aggregates, showed that highest stability, as measured by the Marshall Stabilometer, were produced when slag was used as the aggregate. (The report carrying these Conclusions has already been referenced by the authors, Waterways Experiment Station Technical Memorandum No. 3-254, "Investigation of the Design and Control of Asphalt Paving Mixtures.")

Actually, the service performance of slag macadam bases has been so favorable that engineers and public officials who have had opportunity to witness its outstanding record are most enthusiastic in recognizing its superiority in this respect. For that reason, most Specifications for macadam bases and bituminous surfaces now recognize slag along with limestone, as the preferred aggregate. For reference see the following Specifications:

A. S. T. M. Designation D 693-49, "Crushed Stone and Crushed Slag for Bituminous Macadam Base and Surface Courses."

A. A. S. H. O. Designation M 75-49, "Crushed Stone and Crushed Slag for Base Course"; M 76-49, "Crushed Stone and Crushed Slag for Bituminous Concrete Base Course"; M 77-49, "Crushed Stone and Crushed Slag for Waterbound Surface Course"; M 78-49, "Crushed Stone and Crushed Slag for Bituminous Macadam Surface Course"; M 79-49, "Crushed Stone and Crushed Slag for Bituminous Concrete Surface Course."

Federal Specification SS-C-746a, "Crushed Stone and Crushed Slag (for) Waterbound Base or Wearing Course."

C. A. A. "Standard Specifications for Construction of Airports", Item P 205, "Crushed Stone or Crushed Slag for Dry-Bound Macadam Base Course; Item P 206, "Crushed Stone or Crushed Slag for Water-Bound Macadam Base Course"; Item P 214, "Crushed Stone or Crushed Slag for Penetration Macadam Base Course."